Humus, its structure and role in agriculture and environment
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CARBON AND NITROGEN DYNAMICS IN SOIL IN LONG TERM FIELD EXPERIMENTS

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ABSTRACT
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The Lauchstädt Static Experiment was laid out in loess chernozem soil in 1902. In 1978 the experiment was enlarged. The influence of different organic and mineral fertilizers at different starting levels (up to 0.65 % Ct) was investigated. In a pendant experiment the influence of different organic manures at equal starting level was shown.

Without application of organic manure changes of the Ct-content after 10 years were lower than 0.1 %. There is the same relationship with regard to the nitrogen content. Within 10 years the different starting levels decreased up to 50 % without application of mineral fertilizer. After 10 years organic manure application (125 rsp. 150 dt/ha.a farmyard manure) significant changes up to 0.2 % Ct have been observed. The hot water extractable carbon reflects well the level of organic matter supply of the soil and the amount of mineralizable nitrogen.

INTRODUCTION

Investigations of carbon and nitrogen dynamics in soil are very difficult and expensive, because

- the spatial and temporal variability of these variables are very high
- changes occur practically only in the mineralizable fraction of organic matter. The content of mineralizable carbon in arable soil is 0.3 to 0.9 %. Depending on the texture it is 20 % to 80 % of Ct. That's why relative data to Ct are without value for assertion
- dimension, duration and direction of changes depend on the starting level. Excepting long term experiments, it is very difficult to define the starting level. Starting from different levels, equal treatments may also cause very different changes.

As it is well known from results of long term experiments there's an equilibrium of the total content of C and N in soil reaching a steady state if management practice does not change

over a long period. Equilibration time depends on the difference between starting level and the new steady state. The greater the difference the longer the time of equilibration.

Long term experiments with great differences in the levels of organic matter and continuous investigations of soil are necessary to quantify the C- and N-dynamics.

As far as extending of the experiment and the long period of investigations concern, the Static Experiment Lauchstädt is ideal for this aim.

2 MATERIAL AND METHODS

The Lauchstädt Static Experiment was laid out in loess chernozem soil in 1902 by Schneidewind and Gröbler in a dry region in the central Germany with only 480 mm average year rainfall. Three large plots were treated with 1) no farmyard manure, 2) 20 t/ha farmyard manure every second year and 3) 30 t/ha farmyard manure every second year, each plot being divided for mineral fertilization with NPK, NP, NK, N, P and no fertilization. Sugar beet, spring barley, potato and winter wheat followed each other, each crop being grown in one field every year. In 1978, the experiment has been enlarged within different levels of C, as consequence of the various manuring in 1902 to 1977, 2 levels of farmyard manure ("without" and "30 t/ha every two years") in orthogonal combination with 5 levels of mineral nitrogen are examined.

In 1978 a further long term fertilizing experiment was laid out with 12 various organic manures in combination with 5 levels of N.

Total C-content was determined following Ströhlein, total N-content following Kjeldahl.

3 RESULTS

As demonstrated in previous publications, after an experimental period of 28 years the content of both total carbon and total nitrogen in all variants (with manure and combination of manure with mineral fertilizer respectively) do not change any more.

A comparison of the total C and total N content over the period 1972 to 1981 and 1982 to 1988 (Fig. 1) confirmed that steady state is practically reached in all treatments.

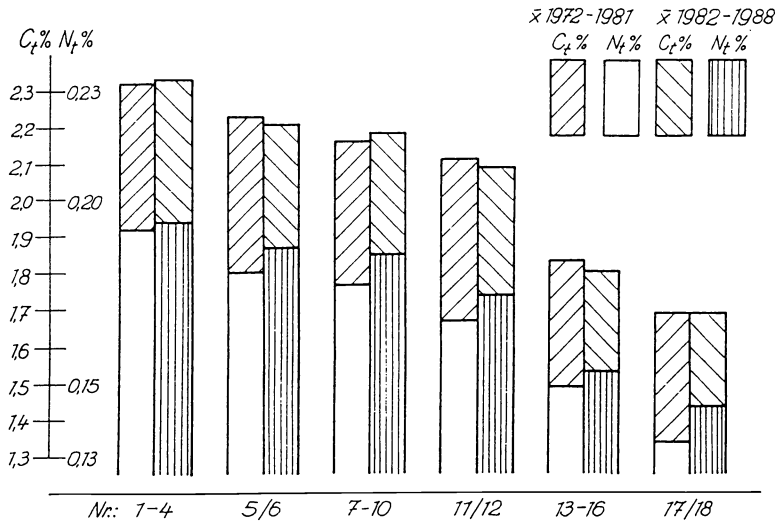


Fig. 1. Static Experiment Lauchstädt: Total C and N in 0 - 20 cm, average from substrip 2, 3, 6 and 7.

The development of N-content shows an insignificant increase, possibly the consequence of increasing yields in last decades, especially those of cereals, in connection with increasing post harvest and root residues. Further investigations are necessary to corroborate this tendence.

The difference in Ct-content between zero variant and the testament with the highest fertilizing level is of 0.65 %, in Nt-content of 0.06 %. In the steady state 5 t/ha.a farmyard manure correspond to a difference in Ct-content of 0.16 % and 6.4 t/ha respectively.

After enlarging the experiment in 1978 the influence of different levels of organic matter, that means C levels, on the N release of soil was investigated (Fig 2).

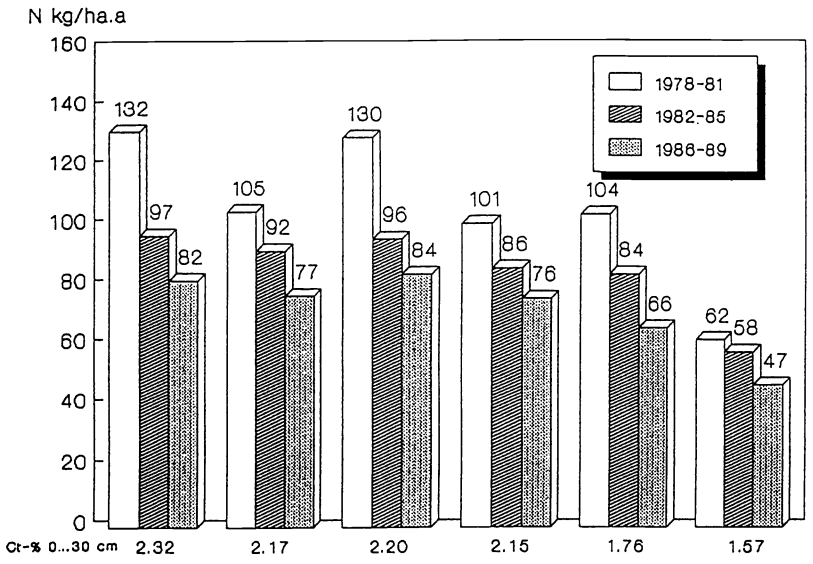


Fig. 2. Influence of different Ct-content in soil on the N uptake: Static experiment Lauchstädt after enlarging the experiment in 1978 without fertilization (spring barley, potatoes, winter wheat, sugar beet).

In the first rotation the N uptake by the plants is between 62 and 132 kg/ha.a. Apparently there are no differences between treatments 1 and 3 on the one hand and 2,4 and 5 on the other hand. In the second rotation, differences between the two extreme variants were nearly halved, this tendency was going on in the third rotation.

To demonstrate the Ct and Nt variations in the soil, all plots were investigated every year. Fig. 3 shows the Ct-content changes of some treatments in comparison to the average data of the whole experiment. Without organic manure the Ct-content changed only insignificantly during the decade. In 1977 the total difference is of 0.56 % of Ct, in 1988 still 0.51 % of Ct. Rather higher are the differences in Nt-content. During the same period Nt changed from 0.057 % to 0.045 %, that corresponds to 500 kg/ha as difference between the treatments in the N uptake.

In the same period changes in Ct and Nt seemed to be faster in variants with organic manure.

The differences decreased as follows: Ct 0.65 % to 0.39 %, Nt 0.068 % to 0.041 %.

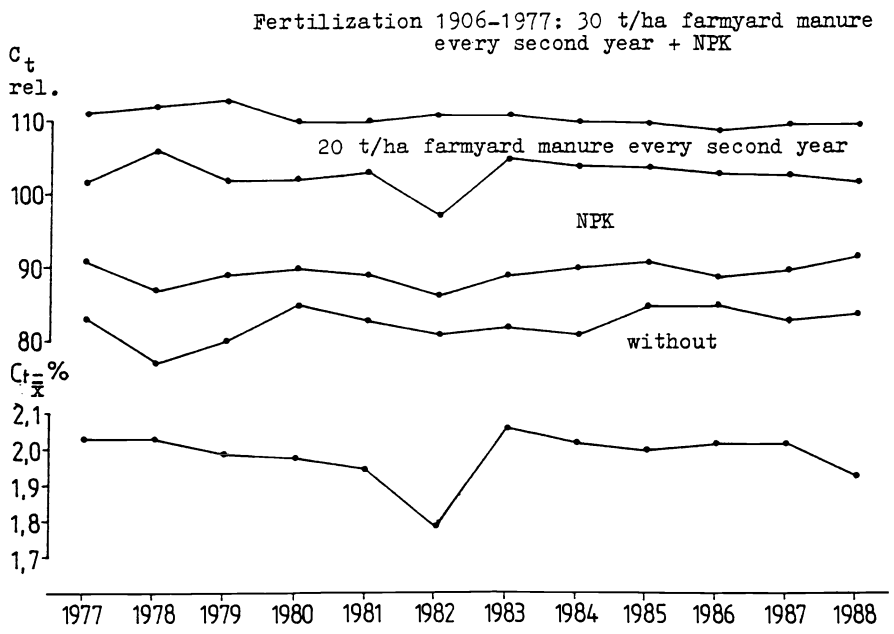
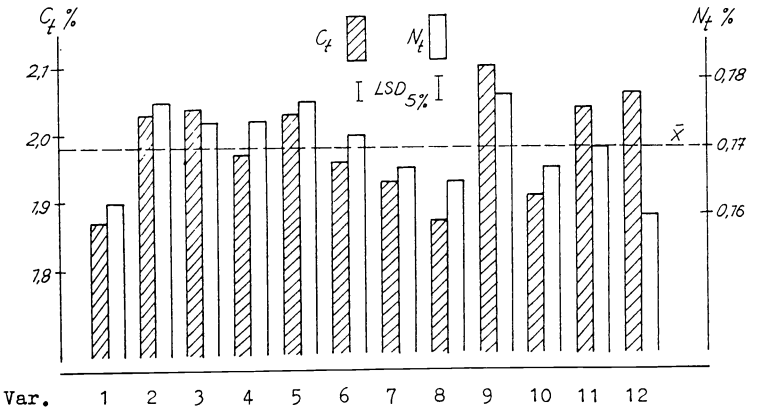


Fig. 3. Variation of Ct-content (0 - 30 cm) in the Static Experiment Lauchsädt after enlarging experiment in 1978 without organic manure and with mineral N, x of 10 and 20 rep. resp.

But also in this case, the steady state will not be reached within the next ten years.

The influence of different organic manure on humus content was investigated over the same period by another experiment (Fig. 4). In this experiment the treatments 7 to 12 get organic manure corresponding to 12 dt C/ha.a.

Application of green manure introduced different amounts of organic substances, on the average more than 12 dt C/ha.a. Green manure variants additionally got 100 kg N/ha.a before sowing. As shown in fig. 4, the Ct-content of the treatments with farmyard manure and compost are higher than in the N content of all treatments is significantly lower than that of green manure variants. After 10 years the greatest difference is of 0.22 % Ct only in this experiment, too. The wide C/N-ratio in the treatments with compost is remarkable.



1 without manure
2 legumes as green manure
3 legumes as fodder
4 phazelia as green manure
5 cruciferes as green manure
6 cruciferes as fodder
7 liquid manure
8 straw + liquid manure
9 farmyard manure
10 straw
11 peat compost
12 brown coal compost

Fig. 4. Influence of different organic manure on the total C and N (0 - 20 cm) content after 10 years in loess chernozem in Lauchstädt, x 1986 - 1988

Considering the Nt changes in the soil layer 0 - 30 cm after 10 years, N balances of some selected treatments show the highest gain in the cultivation of cruciferes as a stubble crop for fodder. This gain amounts to 33 kg/ha.a, even if N application doses are 296 kg/ha.a.

Post harvest and root residues are sufficient to keep or to increase the N-pool in the soil. Stubble crops as green manure cause comparatively unfavourable N balances, becauses the fresh matter in the soil will be transformed relatively quickly, especially in a very warm winter. In connection with this fact high N losses are possible.

Farmyard manure with high doses of mineral nitrogen also cause high N losses, because the turnover occurs very slowly.
A considerable part of nitrogen is mineralized only in summer. Crops with a short vegetation time, like cereals and early potatoes, cannot utilize the nitrogen mineralized in summer months.

TABLE 1

Influence of different organic and mineral fertilization on the N balance (kg/ha.a) after 10 years on loess chernozem in Lauchstädt. x 1978 - 1987 (1978 - 1983 potatoes, followed by w.-wheat, spring barley, sugar beet, spring barley).

Treatment		total N fertiliz.	N uptake	changes in soil N 0 - 30 c	gain (+) loss (-)
1.1.	without	-	114		+ 82
2	organic	36.5	141		+ 72.5
3	manure	73	160	- 32	+ 55
4		109.5	177		+ 35.5
5		146	190		+ 12
2.1.	cruciferes	90	151		+ 89
2	stubble crop	126.5	162		+ 63.5
3	as green man.	163	169	+ 28	+ 34
4		199.5	171		- 0.5
5		236	177		- 31
3.1.	cruciferes	149	261		+ 120
2	stubble crop	186	276		+ 98
3	as fodder	223	300	+ 8	+ 85
4		259	305		+ 54
5		296	231		+ 33
4.1.	farmyard man.	108	145		+ 69
2	correspond	145	161		+ 48
3	to 108 kg	181	175	+ 32	+ 26
4	N/ha.a	218	186		0
5		254	193		- 29

4 DISCUSSION

In the last years the questions of optimal humus content, turnover of organic matter in the soil and possibilities of its conservation in connection with a quantification of N release received more attention, especially from ecological point of view.

The results obtained as well as results from other experiments on the same site prove that changes of Ct and Nt in the soil occur very slowly. Even in the case of great differences between the initial level and absence of organic manure, changes after 10 years are barely measurable. The steady state will be reached only after many decades.

Enrichment of the humus content of a very poor soil by regular

application of organic manure occurs faster than impoverishment of an enriched soil without any manuring.

In dependence of humus content and climatic conditions, N release from the soil is of 50 to 250 kg/ha.a, including N from other sources like immission, which is calculated more than 50 kg N/ha.a.

High humus contents are connected with a high N release and the danger of N losses and environmental pollution, when there is no continuous N uptake by plant cover. On the other hand, in the black earth in Lauchstädt with an ideal texture, sufficient content of organic matter is attainable with post harvest and root residues only and with optimal regime of mineral fertilization.